Existing Building Upgrades
Greg Swiss - Building Energy Specialist

Smart Energy Design Assistance Center (SEDAC), University of Illinois at Urbana Champaign
Providing effective strategies for public and private buildings in Illinois
SEDAC Illinois K-12 School Energy Use Intensities

New Schools, < 20 years old
Expectations

Energy Cost Savings vs. Investment Costs

- Low Hanging Fruit
- Moderate Cost
- Capital Intensive
Expectations

100,000 sf building
$1.00/sf energy costs

Savings from upgrades
~$15,000-$30,000 annually

Over 5 years $75-150k
Space Heating
45%

Interior Lighting
20%

Cooling
15%

Fans Pumps
8%

Plug Loads
8%

Exterior Lighting
2%

Water Heating
2%

Building Cost Breakdown
What you can upgrade

**Lighting**
- Interior/Exterior
- Exit Signs

**Envelope**
- Air sealing
- Insulation
- Glazing (Windows Doors)

**Mechanical Equipment**
- Retro-commissioning
- Ventilation (controls)
- Temperature Setback
- Variable Speed Drives
- Heating (efficient boilers/furnaces)
- Cooling (high-efficiency cooling systems)

These measures either have a **short payback** or **significantly reduce energy** or both!
Efficient Lighting

Interior lighting upgrades

✓ Planning upgrades…key steps
  • Identify and meet lighting needs
  • Select energy efficient lighting equipment
  • Control lighting appropriately for use

*IESNA = Illuminating Engineering Society of North America (aka IES)
Where is lighting today

- **HID**
  - Current system efficacy 105 lm/W
  - Announced 140-150 lm/W

- **Linear Fluorescent**
  - Slow but steady increase & longer life

- **Induction**
  - Little or no progress. Low-cost products are catching up on lumen maintenance

- **LED**
  - Fast improvements. Efficacy difference between lab and products. DOE prognosis 150 lm/W by 2020 and 200 lm/W by 2030
What to What

T12s

T8s 800 Series or T5s
Efficient Lighting

Interior lighting upgrades

Compare current light levels (fc) with IESNA recommended levels.*

Too high consider:
- removing lamps
- low power ballast
- low wattage lamps

*IESNA = Illuminating Engineering Society of North America (aka IES)
Efficient Lighting

Controls
- Occupancy (manual on/ auto off)
- Daylight harvesting (photo cells)
- Bi-level switching (stairwells, garages)
- Dimmers
- Timers
Efficient Lighting

Examples:

- **T12 to T8**
  
  48” four-lamp fluorescent fixture
  
  40W T12 to 28W T8

  **Annual cost savings per fixture:** **$12.75/yr (33% savings)**

  Vacancy sensors or time clocks can further reduce use/consumption.

- **Warehouses, gyms, manufacturing, etc.:**

  High-bay lighting one-for-one fixture replacement
  
  400W Metal halide to Six-lamp 32W T8 high-bay fluorescent

  **Annual cost savings per fixture:** **$60.35/yr (51% savings)**

Good sustainable lighting designer can help assure greatest savings.
### Efficient Lighting – Examples

**Interior lighting upgrades**

**Example 1: Delamp Overlit Rooms** – Remove 1 of 4 T8 lamps to bring classrooms from 80fc to 50fc.

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh</td>
<td>kW</td>
</tr>
<tr>
<td>64,001</td>
<td>36</td>
</tr>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

**Example 2: Gym Lighting Upgrade** – Replace 460W MH with 6-lamp T5 high bay fixtures.

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>Estimated Cost</th>
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<tbody>
<tr>
<td>kWh</td>
<td>kW</td>
</tr>
<tr>
<td>29,484</td>
<td>16</td>
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</tr>
</tbody>
</table>

**Example 3: LED Exit Retrofit** – Retrofit incandescent exit lamps with LED kits.

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh</td>
<td>kW</td>
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<td>18,396</td>
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*Example – 117,000 SF High School built in 2001 code min. construction.*
Efficient Lighting – Example

Interior lighting upgrades

DCEO CASE STUDY
Large Lighting Retrofit

Argonne National Laboratory, Chicago, IL

<table>
<thead>
<tr>
<th>Client</th>
<th>University of Chicago</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building type</td>
<td>Research Laboratory</td>
</tr>
<tr>
<td>Energy measures implemented</td>
<td>Lighting, controls</td>
</tr>
<tr>
<td>Total project cost</td>
<td>$172,000</td>
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<tr>
<td>Projected annual energy savings</td>
<td>$39,000</td>
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<tr>
<td>Total DCEO incentive</td>
<td>$49,960</td>
</tr>
<tr>
<td>Payback period without incentives</td>
<td>4.4 years</td>
</tr>
<tr>
<td>Payback period with incentives</td>
<td>3 years</td>
</tr>
</tbody>
</table>

Incentive ~30%

One of five buildings to receive lighting upgrades in 2010

LIGHTING EFFICIENCY AND CONTROLS
Efficient Lighting

Exterior lighting upgrades

✓ Assessing what you have
  • Light levels
  • Lamp nominal wattage
  • Ballast type
  • Ballast factor
  • Controls
Efficient Lighting

Exterior lighting upgrades

✓ Planning upgrades…key steps
  • Identify and meet lighting needs
  • Select energy efficient lighting equipment
  • Control lighting appropriately for use

• SEDAC does not typically recommend any one particular outdoor lighting technology
• We recommend working with qualified lighting designers and vendors
• Require providers to optimize equipment selection, layout, and control to minimize energy consumption and provide the lowest life cycle cost.
Efficient Lighting

Exterior lighting upgrades

✓ Planning upgrades…key steps

• Select energy efficient lighting equipment
  • High efficacy lamps
    (high lumens per watt)
  • Long lamp life
  • Whole assembly efficiency
    (lamp + ballast + fixture)
Efficient Lighting

Exterior lighting upgrades

✓ Planning upgrades…key steps
  • Control lighting appropriately for use
    • Motion sensors
    • Astronomical time clocks
    • Partial night lighting (bi-level)
Efficient Lighting - Example

Exterior lighting upgrades

DCEO CASE STUDY
Parking Garage Lighting

City of Peoria - Jefferson St. Parking Deck

<table>
<thead>
<tr>
<th>Client</th>
<th>City of Peoria</th>
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<tbody>
<tr>
<td>Building type</td>
<td>Parking Garage</td>
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<td>Energy measures implemented</td>
<td>Lighting retrofit</td>
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<td>Total project cost</td>
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<td>Total DCEO incentive</td>
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<tr>
<td>Payback period without incentives</td>
<td>3 years</td>
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<tr>
<td>Payback period with incentives</td>
<td>1.7 years</td>
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43% incentive
Air sealing/ Weatherization

Reducing air leakage

✓ Assessing current conditions

• All existing buildings… have some infiltration and exfiltration.
• Incoming air needs conditioning
Air sealing/ Weatherization

Reducing air leakage

✓ Assessing current conditions
  • Finding leaks can often be fairly easy.

Check joints, penetrations, plumbing chases, windows and doors.
Air sealing/ Weatherization

Reducing air leakage

✓ Planning upgrades

- Fixing leaks can also be quite straightforward
  - Caulking and Spray Foam
  - Weather stripping, thresholds
  - Rigid insulation (faced, taped)
  - Vestibules
Insulation Upgrades

Roofs and walls

✓ Assessing current thermal envelope
  • Look for opportunities to upgrade with:
    • Roof replacement
    • Air sealing projects
    • Change of use (e.g. auto shop becomes office space)
    • Locations with easy access (attics, infill spaces)
Insulation Upgrades

Roofs and walls

✓ Planning upgrades

  • Meet or exceed current prescriptive total assembly insulation levels

  ✓ Roofs:
    • Insulation entirely above deck – R-25.0 continuous
    • Attic insulation – R-49.0 (U-0.021)

  ✓ Walls:
    • Mass (concrete or masonry) – R-13.3 continuous
    • Steel framed – R-13.0 + R-10.0 continuous (U-0.055)
    • Walls below grade – R-10.0 continuous

  ✓ Slabs:
    • Unheated slabs - perimeter insulation – R-10 for 24 in.
    • Heated slabs – perimeter insulation – R-15 for 36 in.

Values from ANSI/ASHRAE/USGBC/IES Standard 189.1-2011
Standard for the Design of High-Performance Green Buildings

• Incorporate air sealing to further improve performance
Glazing Upgrades

All envelope openings including doors, skylights, overhead doors, etc.

✓ Assessing current openings
  • Look for opportunities to upgrade with:
    • Leaking and/or damaged openings
    • Comfort upgrades
    • Air sealing projects
    • Change of use (e.g. warehouse to office space)
Glazing Upgrades

All envelope openings including doors, skylights, overhead doors, etc.

✓ Planning upgrades
  - Double-Glazed with Low-Solar-Gain Spectrally Selective Low-E Glazing
  - Argon Gas Fill
  - Thermally Broken Frames
  - Detail and Test for Air Tight Installation
Glazing Upgrades

All envelope openings including doors, skylights, overhead doors, etc.

✓ Planning upgrades
  • Meet or exceed current prescriptive total assembly performance characteristics

✓ Total assembly includes frame, spacers, glazing

✓ Opaque Doors:
  • Swinging Doors ≤ U-0.40 (≥ R-2.5)
  • Non-Swinging ≤ U-0.40 (≥ R-2.5)

✓ Metal frame windows:
  • Curtainwall/ Storefront ≤ U-0.35 (≥ R-2.9)
  • All other (punched openings) ≤ U-0.45 (≥ R-2.2)

✓ Skylights without curb:
  • ≤ U-0.45 (≥ R-2.2)

✓ Solar Heat Gain Coefficient (SHGC) – 0.35

Values from ANSI/ASHRAE/USGBC/IES Standard 189.1-2011
Standard for the Design of High-Performance Green Buildings

• Emphasize air sealing to further improve performance
Retro-Commissioning

For HVAC Equipment

✔ What is retro-commissioning?

• The process of ensuring that building systems operate as intended.
Retro-Commissioning

Monthly Gas Usage

- Therms
- Heating Deg Days

Graph showing monthly gas usage with peaks in February, April, October for Therms and Heating Deg Days.
Retro-Commissioning
For HVAC Equipment
✓ Planning upgrades
  • **Testing**
    • Trending equipment operation using:
      • Building automation system (BAS)
      • Independent data loggers (e.g. Hobo® temp, RH, light level loggers; motor on/off logger; etc.)
      • Functional testing of actuators, sensors (including thermostats, CO2 sensors, RH sensors, etc.), and more.
  • **Adjusting**
    • Schedules
    • Control setpoints
    • Expectations
  • **Training**
    • Without training, persistence is unlikely
Temperature Setbacks

No Brainer

<table>
<thead>
<tr>
<th>Time</th>
<th>Unoccupied</th>
<th>Occupied</th>
<th>Unoccupied</th>
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<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
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<td>3</td>
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<tr>
<td>12</td>
<td></td>
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</tr>
</tbody>
</table>

Temperature

- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80

Time

1  2  3  4  5  6  7  8  9  10  11  12
Temperature Setbacks

Temperature vs. Time Graph:

- **Temperature** on the y-axis.
- **Time** on the x-axis, ranging from 1 to 12.
- **Unoccupied** and **Occupied** periods indicated.
- **WINTER** highlighted.
Temperature Setbacks

Temperature (°F)

Time

Unoccupied
Occupied
Unoccupied

Summer

72 73 74 75 76 77 78 79 80 81

1 2 3 4 5 6 7 8 9 10 11 12
Temperature Setbacks

Basics
- Up in the summer & down in the winter
- Optimize the schedules by zones

Advanced (BAS Users)
- Using optimum start/stop controls logic
- Using optimum start/stop *experiential* logic.
Heating

Steam Boilers

✓ Assessing current equipment
  • High pressure? Medium? Low?
  • Age of the existing boiler?
  • Is the efficiency known?
  • Any records of combustion analysis?
  • Capacity? Oversized? Undersized?
  • Is steam provided throughout building or is it used to heat water in a heat exchanger?
  • Are there steam traps? How many?
  • Steam trap maintenance program?
  • Manual or automated blowdown?
  • Heating only or also used for production of DHW? Pool heating?
Heating
Steam Boilers

✓ Planning upgrades
  • Steam trap maintenance
  • Boiler tune-up – clean, fuel/air adjustment
  • Spark ignition
  • Energy-efficient burners- induced draft
  • Controls upgrades
  • Automatic flue dampers
  • Stack economizers
  • Pipe insulation

✓ Boiler replacement:
  ✓ Consider age
  ✓ Right-sizing
  ✓ High efficiency steam boilers (80-83%)
  ✓ Consider system conversion to use higher efficiency hot-water boiler(s) (92%+)
  ✓ Advanced controls (O2 trim, auto blow down).
Heating

Hot Water Boilers

✓ Assessing current equipment
  • Age of the existing boiler?
  • Is the efficiency known?
  • Condensing or non-condensing?
  • Capacity? Oversized? Undersized?
  • Temperature of water provided
  • Temperature of return water
  • Are there outdoor reset controls?
  • Size of pumps (HP)
  • Control of pumps
  • What systems does it serve:
    • Coils in air handlers & mixing boxes
    • Baseboard heaters, wall convectors, unit heaters
    • DHW or pool heat exchanger
Heating

Hot Water Boilers

✓ Planning upgrades
  • Boiler tune-up
  • Energy-efficient burners
    • Hot water reset
  • Automatic flue dampers
  • Burner control upgrades
    • VFDs on pumps
    • Boiler replacement:
      ✓ Right-sizing
      ✓ Modular
      ✓ Condensing
      ✓ High Efficiency (92%+)
      ✓ Advanced controls – O2 trim
Add a Condensing Boiler – Supplement the two original boilers with a high efficiency modular condensing unit. This will run at peak efficiency during most of the low-load heating hours.

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh</td>
<td>kW</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Gas for heating ≥ $75,000/yr

- Full engineering analysis is necessary.
- Isolate the two old boilers with valves.
- AKA: Shoulder Boiler or Front-Loaded Boiler
- Full upgrade is always an option if funds allow.

Example – 117,000 SF High School built in 2001 code min. construction.
Cooling

Chillers

✓ Assessing current equipment
  • Air or water cooled?
  • Age of the existing equipment?
  • Efficiency?
  • Tonnage? Oversized? Undersized?
  • Vapor compression or absorption?
  • Reciprocating, scroll, screw-driven, or centrifugal compression?
  • $\Delta T$ between supply and return chilled water
  • Size (HP) and control of pumps for chilled water systems
  • Regular maintenance?
Cooling

Chillers

✓ Assessing current equipment
  • Computer room cooling systems
  • Once-through domestic water cooling systems
Cooling

Chillers

✓ Planning upgrades
  • Chiller tune-up
  • Temperature resets
  • VFDs on pumps
  • Controls upgrades
  • Chiller replacement:
    • Right-sizing
    • Larger systems: Water Cooled Centrifugal ≥ 5.9 COP (≤ 0.6 kW/ton) Full Load
    • Smaller systems: Air Cooled Chillers ≥ 2.9 COP (≥ 10.0 EER)
    • Advanced controls—desuperheating, floating head pressure, condenser heat recovery
Building Cost Breakdown

- Space Heating: 45%
- Interior Lighting: 20%
- Cooling: 15%
- Fans Pumps: 8%
- Plug Loads: 8%
- Exterior Lighting: 2%
- Water Heating: 2%
Ventilation

- Heating: 45%
- Envelope: 20%
- Ventilation: 25%
- Water Heating: 2%
- Exterior Lighting: 2%
- Interior Lighting: 20%
- Cooling: 15%
- Fans Pumps: 8%
- Plug Loads: 8%
Ventilation

Modulate ventilation rates

✓ Assessing current ventilation
  • Are current ventilation rates appropriate?
  • Measure/ trend CO2 levels
  • How is ventilation currently controlled?
  • Incoming air typically needs conditioning
Ventilation

Modulate ventilation rates

✓ Planning upgrades
  • Modulate ventilation rates using demand-based control (based on occupancy) using:
    • Sensed CO2 levels
    • Occupancy tracking (in security controlled buildings)
Ventilation

Modulate ventilation rates

✓ Planning upgrades

• Modulate ventilation rates using economizer control to:
  • Reduced cooling load
    
    *Conditioning outside air is more energy efficient than conditioning recirculated air when the enthalpy (heat + humidity) of the outside air is less than the enthalpy of recirculated air.*

  • Free cooling
    
    *When the outside air is both sufficiently cool and sufficiently dry (depending on the climate) no additional conditioning may be needed.*

• Use economizer control year-round when appropriate for significant reduced mechanical cooling energy use.
Ventilation

Ventilation energy recovery

✓ Planning upgrades
  • Consider ventilation exhaust energy recovery for new air handling equipment.

Select total energy recovery – enthalpy wheel (sensible and latent heat transfer, can provide dehumidification in summer, humidification in winter).
Ventilation - Example

Modulate ventilation rates

Example

**Demand Control Ventilation** – Reduce the amount of outdoor air brought into the building by monitoring need with CO2 sensors.

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh</td>
<td>kW</td>
</tr>
<tr>
<td>71,248</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
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</table>

- Scheduling ventilation typically only closes ventilation louvers at night and on weekends.
- Modern CO₂ sensors are self-calibrating
- Typically ≤ 1,100 ppm avoids odors.
- Occupancy override buttons in space can allow for more aggressive scheduling.

Example – 117,000 SF High School built in 2001 code min. construction.
Electric Motor Control

Variable Frequency Drives (Variable Speed Drives)

✓ Planning upgrades
  • Fans and pumps with variable torque loads
    • Significant energy savings
    • Soft start potential
    • Manual override recommended
    • Lower motor maintenance
    • Extended motor life
    • Training recommended
Electric Motor Control - Example

Variable Frequency Drives (Variable Speed Drives)

Example:

**VFDs on Heating Loop Pumps** – Reduce the speed of the heating loop pumps with VFDs. Control the VFD based on pressure in the line.

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh kW Therms</td>
<td>$</td>
</tr>
<tr>
<td>36,829 0 (370)</td>
<td>$3,512 $8,250</td>
</tr>
</tbody>
</table>

- To control based on pressure, valve bypass loops must be removed. (i.e. Replace three-way valves with two-way valves.)
- VFDs are not useful unless you are going to turn down the flow, or replace flow restrictors.

Example – 117,000 SF High School built in 2001 code min. construction.
# Case Studies

## Multiple Retrofits

<table>
<thead>
<tr>
<th>Client:</th>
<th>City of Decatur</th>
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<tbody>
<tr>
<td>Building Type:</td>
<td>Civic Center</td>
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<tr>
<td>Energy Measures Implemented:</td>
<td>High Efficiency Lighting Occupancy Sensors Boiler Pump Controls Chiller Water Pump Sequencing</td>
</tr>
<tr>
<td>Projected Annual Energy Savings:</td>
<td>682,383 kWh</td>
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<tr>
<td>Projected Annual Cost Savings:</td>
<td>$60,000</td>
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<tr>
<td>Total Energy Incentive:</td>
<td>$25,496</td>
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<tr>
<td>EECB Grant:</td>
<td>$283,054</td>
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<tr>
<td>Project Cost:</td>
<td>$308,550</td>
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<tr>
<td>Payback Period with Incentives:</td>
<td>0.45</td>
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**RETOFIT SAVINGS POTENTIAL & INCENTIVES**
**Case Studies**

Multiple Retrofits

**KENWOOD ELEMENTARY**

<table>
<thead>
<tr>
<th>Client:</th>
<th>Champaign Unit 4 School District</th>
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<tbody>
<tr>
<td>Building Type:</td>
<td>Elementary School</td>
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<tr>
<td>Project Goals:</td>
<td>Reduce operating costs</td>
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<tr>
<td></td>
<td>Provide year-round comfort</td>
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<tr>
<td>Energy Measures Implemented:</td>
<td>Air sealing</td>
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<tr>
<td></td>
<td>Window replacement</td>
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<tr>
<td></td>
<td>Condensing boilers</td>
</tr>
<tr>
<td></td>
<td>High efficiency lighting</td>
</tr>
<tr>
<td>Projected Energy Savings:</td>
<td>$16,933 per year</td>
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<td>Projected Capital Cost:</td>
<td>$138,801</td>
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<td>Total DCEO Incentives:</td>
<td>$21,165</td>
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**RETROFIT SAVINGS POTENTIAL & INCENTIVES**
SEDAC Energy Assessment for Existing Buildings

- **FREE** SEDAC Building Energy Assessment includes:
  - Bill analysis
  - Current energy cost breakdown
  - Benchmarking
  - Site visit
  - Quick list of potential measures
  - Analysis of potential incentives
  - Final report with quantified recommendations
    - L3 reports also include an economic analysis
  - Follow-up assistance
  - Implementation tracking
To Get Started

✓ Start with our 1 page application
  • Include square footage, account numbers, annual energy cost totals

✓ Then the client provides:
  • 24 months of gas & electric bills
  • Building plans, layout, mechanical schedules as available
  • Site visit with appropriate personnel (2-4 hrs)
  • An energy champion to get things done
Thank you.

Web site: www.sedac.org
Contact: info@sedac.org
1-800-214-7954